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## Use of water-redispersible polymer powders in building adhesive compositions

The invention relates to the use of water-redispersible  
5 polymer powders based on protective colloid stabilized  
vinyl ester polymers in building adhesive compositions.

Polymers stabilized by protective colloids are used in  
particular in the form of their aqueous dispersions or  
10 water-redispersible polymer powders in diverse  
applications, as coating compositions or adhesives, for  
example, for a very wide variety of substrates: for  
example, as cementitious tile adhesives. The protective  
colloids used are generally polyvinyl alcohols. The use  
15 of polyvinyl alcohol is worthwhile because, in  
comparison to systems stabilized by low molecular mass  
compounds, such as emulsifiers, polyvinyl alcohol makes  
its own contribution to strength (e.g., tensile  
adhesion values in the tile adhesive). Monomers used to  
20 prepare redispersible powders have to date been  
preferably vinyl esters and ethylene. When the vinyl  
ester/ethylene combination is used, the establishment  
of stability with respect to saponification  
necessitates a high ethylene content, which reduces the  
25 Tg. This may have adverse effects on the tensile bond  
strength of the tile adhesives, especially after  
storage under hot conditions. What is desirable,  
however, is a high and constant level of the tensile  
bond strengths in the tile adhesive after storage under  
30 any conditions (dry, wet, heat and freeze/thaw).

Especially when polymers are used in the form of their  
redispersion powders to improve the properties of  
mortar, a major field of use for redispersion powders,  
35 the formulations are required to remain stable for a  
certain time and must not suffer any substantial  
alteration in their processing consistency (viscosity  
stability or cement stability); indeed, a user cannot  
be expected to have to stir up a new mixture within a

short time span. In the concrete and mortar industry, furthermore, an important part is played by the mechanical properties, such as the compressive strength, the porosity and thus the air pore content.

5 If there are too many air pores, the compressive strength falls sharply; if there are too few, or no, air pores in the mortar or concrete, the building material will lack sufficient freeze/thaw stability.

10 DE-A 21 48 456 (GB-A 14 07 827) discloses building adhesives based on copolymers containing hydroxyl-containing silicon compounds in copolymerized form. EP-B 35332 describes tile adhesives based on styrene-acrylate copolymers, containing not only hydroxyl-  
15 containing silicon compounds but also relatively large amounts - up to 10% by weight - of copolymerized (meth)acrylic acid units. In EP-A 640630, it is recommended, for the purpose of preparing tile adhesives, to use silicon-modified polymer dispersions  
20 containing up to 4% by weight of ethylenically unsaturated carboxamides in copolymerized form.

It is an object of the invention to provide stable, low-viscosity, protective colloid stabilized dispersion  
25 powders based on vinyl ester polymers which, when used in cementitious applications, possess a completely satisfactory viscosity stability or cement stability and which do not hinder the setting of the cement. A further object is to provide redispersible powders  
30 which have better and more consistent tensile bond strengths after storage under any conditions.

Normally, the use of hydrophobic monomers is preferred in order to obtain water-resistant products. It has  
35 surprisingly now been found that better tensile bond strengths, even after storage under wet and freeze/thaw conditions, are observed when hydrophilic water-soluble monomers are used.

5 The invention provides for the use of water-  
redispersible polymer powders based on protective  
colloid stabilized vinyl ester polymers in building  
adhesive compositions, wherein the vinyl ester polymers  
contain from 0.2 to 1.5% by weight, based on the  
overall weight of the vinyl ester polymers, of  
auxiliary monomer units derived from monomers having a  
higher water solubility than vinyl acetate, the  
10 solubility of vinyl acetate in water being  
approximately 2 g per 100 g of water under standard  
conditions.

15 Suitable auxiliary monomers are ethylenically  
unsaturated monocarboxylic and dicarboxylic acids and  
their anhydrides, preferably acrylic acid, methacrylic  
acid, itaconic acid, crotonic acid, fumaric acid and  
maleic acid, and maleic anhydride; ethylenically  
unsaturated carboxamides and carbonitriles, preferably  
20 acrylamide, methacrylamide, acrylamidoglycolic acid and  
acrylonitrile; ethylenically unsaturated sulfonic acids  
and their salts, preferably vinylsulfonic acid and  
2-acrylamido-2-methylpropanesulfonic acid.

25 The amount of auxiliary monomer is preferably 0.5 to  
1.0% by weight, based on the overall weight of the  
vinyl ester polymers.

Suitable vinyl esters are one or more monomers from the  
group of the vinyl esters of branched or unbranched  
carboxylic acids having 1 to 15 carbon atoms. Preferred  
30 vinyl esters are vinyl acetate, vinyl propionate, vinyl  
butyrate, vinyl 2-ethylhexanoate, vinyl laurate,  
1-methylvinyl acetate, vinyl pivalate, and vinyl esters  
of  $\alpha$ -branched monocarboxylic acids having 9 to 11  
carbon atoms, an example being VeoVa9<sup>R</sup> or VeoVa10<sup>R</sup>  
35 (trade names of Shell). Vinyl acetate is particularly  
preferred.

If desired, the vinyl ester polymers may also contain further comonomers from the group of the esters of acrylic acid or methacrylic acid with branched or unbranched alcohols having 1 to 15 carbon atoms, from the group of the olefins, of the vinyl halides and of the monoesters and diesters of ethylenically unsaturated dicarboxylic acids. Preferred methacrylic esters or acrylic esters are methyl acrylate, methyl methacrylate, ethyl acrylate, ethyl methacrylate, propyl acrylate, propyl methacrylate, n-butyl acrylate, n-butyl methacrylate, 2-ethylhexyl acrylate, and norbornyl acrylate. Methyl acrylate, methyl methacrylate, n-butyl acrylate, 2-ethylhexyl acrylate and norbornyl acrylate are particularly preferred. Examples of copolymerizable olefins are ethene and propene. From the group of the vinyl halides, it is common to use vinyl chloride. Suitable monoesters and diesters of ethylenically unsaturated dicarboxylic acids are the monoesters and diesters of fumaric acid and maleic acid, such as their diethyl and diisopropyl esters.

If desired, from 0.05 to 10% by weight, based on the overall weight of the monomer mixture, of further functional comonomers may be copolymerized. Examples thereof are precrosslinking comonomers such as polyethylenically unsaturated comonomers, examples being divinyl adipate, diallyl maleate, allyl methacrylate and triallyl cyanurate, or post-crosslinking comonomers, examples being methylacrylamidoglycolic methyl ester (MAGME), N-methylolacrylamide (NMA), N-methylolmethacrylamide, N-methylolallylcarbamate, alkyl ethers such as the isobutoxy ether or esters of N-methylolacrylamide, of N-methylolmethacrylamide and of N-methylolallylcarbamate. Further examples are silicon-functional comonomers, such as acryloxypropyltri(alkoxy)silanes and methacryloxypropyltri(alkoxy)silanes, vinyltrialkoxysilanes and vinylmethyldialkoxysilanes, examples of alkoxy groups

that may be present being ethoxy and ethoxypropylene glycol ether radicals. Further examples are comonomers containing epoxide groups, such as glycidyl acrylate, glycidyl methacrylate, allyl glycidyl ether, vinyl glycidyl ether, and vinylcyclohexene oxide.

Greatest preference is given to the base polymers specified below, which also contain the water-soluble auxiliary monomers and any functional comonomer units, in the amounts just described. With the fraction of auxiliary monomers and any functional comonomer units, the amounts in % by weight add up to 100% by weight in each case.

- 15 Vinyl ester-ethylene copolymers, such as vinyl acetate-ethylene copolymers, having an ethylene content of preferably from 1 to 60% by weight, further comprising, if desired, fumaric or maleic diesters, preferably their diethyl and diisopropyl esters;
- 20 vinyl ester-ethylene-vinyl chloride copolymers having an ethylene content of preferably from 1 to 40% by weight and a vinyl chloride content of preferably from 20 to 90% by weight, vinyl esters present comprising preferably vinyl acetate and/or vinyl propionate and/or
- 25 one or more copolymerizable vinyl esters such as vinyl laurate, vinyl pivalate, vinyl 2-ethylhexanoate, vinyl esters of an alpha-branched carboxylic acid, especially Versatic acid vinyl esters (VeoVa9<sup>R</sup>, VeoVa10<sup>R</sup>); vinyl acetate copolymers with preferably from 1 to 50%
- 30 by weight of one or more copolymerizable vinyl esters such as vinyl laurate, vinyl pivalate, vinyl 2-ethylhexanoate, vinyl esters of an alpha-branched carboxylic acid, especially Versatic acid vinyl esters (VeoVa9<sup>R</sup>, VeoVa10<sup>R</sup>), further comprising, if desired,
- 35 from 1 to 40% by weight of ethylene; vinyl ester-acrylic ester copolymers containing preferably from 30 to 90% by weight of vinyl ester, especially vinyl acetate, and preferably from 1 to 60%

by weight of acrylic ester, especially n-butyl acrylate or 2-ethylhexyl acrylate, and further comprising, if desired, from 1 to 40% by weight of ethylene;

vinyl ester-acrylic ester copolymers containing preferably from 30 to 75% by weight of vinyl acetate, preferably from 1 to 30% by weight of vinyl laurate or vinyl esters of an alpha-branched carboxylic acid, especially Versatic acid vinyl esters, preferably from 1 to 30% by weight of acrylic esters, especially n-butyl acrylate or 2-ethylhexyl acrylate, and further comprising, if desired, from 1 to 40% by weight of ethylene.

The monomer selection and the selection of the weight fractions of the comonomers are made so that in general the resulting glass transition temperature,  $T_g$ , is from  $-50^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$ , preferably from  $-30^{\circ}\text{C}$  to  $+40^{\circ}\text{C}$ . The glass transition temperature,  $T_g$ , of the polymers can be determined in a known manner by means of differential scanning calorimetry (DSC). The  $T_g$  can also be calculated approximately in advance using the Fox equation. According to Fox T.G., Bull. Am. Physics Soc. 1, 3, page 123 (1956):  $1/T_g = x_1/T_{g1} + x_2/T_{g2} + \dots + x_n/T_{gn}$ , where  $x_n$  represents the mass fraction (% by weight/100) of the monomer  $n$  and  $T_{gn}$  is the glass transition temperature, in kelvins, of the homopolymer of the monomer  $n$ .  $T_g$  values for homopolymers are listed in the Polymer Handbook, 2nd Edition, J. Wiley & Sons, New York (1975).

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Preparation takes place by the emulsion polymerization process or by the suspension polymerization process, preferably by the emulsion polymerization process, the polymerization temperature being generally from  $40^{\circ}\text{C}$  to  $100^{\circ}\text{C}$ , preferably from  $60^{\circ}\text{C}$  to  $90^{\circ}\text{C}$ . Where gaseous comonomers such as ethylene or vinyl chloride are copolymerized it is also possible to operate under pressure, generally between 5 bar and 100 bar.

5 The polymerization is initiated with the water-soluble  
or monomer-soluble initiators, or redox initiator  
combinations, that are customary for emulsion  
polymerization or suspension polymerization,  
respectively. Examples of water-soluble initiators are  
the sodium, potassium and ammonium salts of  
peroxodisulfuric acid, hydrogen peroxide, t-butyl  
peroxide, t-butyl hydroperoxide, potassium peroxo-  
10 diphosphate, tert-butyl peroxopivalate, cumene hydro-  
peroxide, isopropylbenzene monohydroperoxide, and  
azobisisobutyronitrile. Examples of monomer-soluble  
initiators are dicetyl peroxydicarbonate, dicyclohexyl  
peroxydicarbonate, and dibenzoyl peroxide. Said  
15 initiators are used generally in an amount of from 0.01  
to 0.5% by weight, based on the overall weight of the  
monomers.

20 Redox initiators used are combinations of said  
initiators with reducing agents. Suitable reducing  
agents are the sulfites and bisulfites of alkali metals  
and of ammonium, an example being sodium sulfite, the  
derivatives of sulfoxylic acid, such as zinc or alkali  
metal formaldehyde sulfoxylates, for example, sodium  
25 hydroxymethanesulfinatate, and ascorbic acid. The amount  
of reducing agent is preferably from 0.01 to 0.5% by  
weight, based on the overall weight of the monomers.

30 In order to control the molecular weight it is possible  
to use regulating substances during the polymerization.  
If regulators are used, it is normally in amounts of  
from 0.01 to 5.0% by weight, based on the monomers to  
be polymerized, and they are metered in separately or  
else as a premix with reaction components. Examples of  
35 such substances are n-dodecyl mercaptan, tert-dodecyl  
mercaptan, mercaptopropionic acid, methyl mercapto-  
propionate, isopropanol, and acetaldehyde. Preferably,  
no regulating substances are used.

Suitable protective colloids are partially or fully hydrolyzed polyvinyl alcohols. Preference is given to partially hydrolyzed polyvinyl alcohols having a degree of hydrolysis of from 80 to 95 mol% and a Höppler viscosity in 4% strength aqueous solution of from 1 to 30 mPas (method according to Höppler at 20°C, DIN 53015). Also suitable are partially hydrolyzed, hydrophobically modified polyvinyl alcohols having a degree of hydrolysis of from 80 to 95 mol% and a Höppler viscosity in 4% strength aqueous solution of from 1 to 30 mPas. Examples thereof are partially hydrolyzed copolymers of vinyl acetate with hydrophobic comonomers such as isopropenyl acetate, vinyl pivalate, vinyl ethylhexanoate, vinyl esters of saturated alpha-branched monocarboxylic acids having 5 or 9 to 11 carbon atoms, dialkyl maleates and dialkyl fumarates such as diisopropyl maleate and diisopropyl fumarate, vinyl chloride, vinyl alkyl ethers such as vinyl butyl ether, and olefins such as ethene and decene. The fraction of the hydrophobic units is preferably from 0.1 to 10% by weight, based on the overall weight of the partially hydrolyzed polyvinyl alcohol. It is also possible to use mixtures of said polyvinyl alcohols.

Further suitable polyvinyl alcohols are partially hydrolyzed, hydrophobicized polyvinyl alcohols obtained by polymer-analogous reaction, an example being acetalization of the vinyl alcohol units with C<sub>1</sub> to C<sub>4</sub> aldehydes such as butyraldehyde. The fraction of the hydrophobic units is preferably from 0.1 to 10% by weight, based on the overall weight of the partially hydrolyzed polyvinyl acetate. The degree of hydrolysis is from 80 to 95 mol%, preferably from 85 to 94 mol%, and the Höppler viscosity (DIN 53015, method according to Höppler, 4% strength aqueous solution) is from 1 to 30 mPas, preferably from 2 to 25 mPas.



Maximum preference is given to polyvinyl alcohols having a degree of hydrolysis of from 85 to 94 mol% and a Höppler viscosity in 4% strength aqueous solution of from 3 to 15 mPas (method according to Höppler at 20°C, 5 DIN 53015). Said protective colloids are obtainable by means of processes known to the skilled worker.

10 The polyvinyl alcohols are used in general in an amount of in total from 1 to 20% by weight, based on the overall weight of the monomers, in the polymerization. The protective colloid fraction can either be included completely in the initial charge or else included in part in the initial charge and in part metered in. Preferably, at least 5% by weight of the protective 15 colloid are included in the initial charge; most preferably, all of the protective colloid fraction is included in the initial charge.

20 In the process of the invention, polymerization is conducted preferably without adding emulsifiers. In exceptional cases, it may be of advantage to use, in addition, small amounts of emulsifiers, if appropriate from 1 to 5% by weight based on the monomer amount. Suitable emulsifiers include anionic, cationic, and 25 nonionic emulsifiers, examples being anionic surfactants, such as alkyl sulfates having a chain length of 8 to 18 carbon atoms, alkyl or alkylaryl ether sulfates having 8 to 18 carbon atoms in the hydrophobic radical and up to 40 ethylene oxide or 30 propylene oxide units, alkyl- or alkylarylsulfonates having 8 to 18 carbon atoms, esters and monoesters of sulfosuccinic acid with monohydric alcohols or alkylphenols, or nonionic surfactants such as alkyl polyglycol ethers or alkylaryl polyglycol ethers having 35 from 8 to 40 ethylene oxide units.

The monomers can be metered in in their entirety or included in fractions in the initial charge with the

remainder being metered in following the initiation of the polymerization. A preferred procedure is to include from 50 to 100% by weight, based on the overall weight of the monomers, in the initial charge and to meter in the remainder. Metered additions may be conducted separately (spatially and temporarily) or some or all of the components to be metered can be metered in pre-emulsified form. Depending on their chemical nature, the auxiliary monomers likewise may be included in their entirety in the initial charge, or may be metered in. Partial inclusion in the initial charge, and partial metering, are also possible. The degree of monomer conversion is controlled with the metered addition of initiator.

After the end of polymerization, the batch can be postpolymerized using known methods in order to remove residual monomers, by means, for example, of postpolymerization initiated by redox catalyst. Volatile residual monomers can also be removed by means of distillation, preferably under reduced pressure, and, if desired, with the passage of inert entraining gases such as air, nitrogen or steam through or over the batch.

The aqueous dispersions resulting from the polymerization have a solids content of from 30 to 75% by weight, preferably from 50 to 60% by weight. In order to prepare the water-redispersible polymer powders, the aqueous dispersions are admixed if desired with protective colloids as a spraying aid and then dried by means, for example, of fluidized bed drying, freeze drying, or spray drying. Preferably, the dispersions are spray-dried. Spray drying takes place in standard spray-drying units, it being possible for atomization to take place by means of one-fluid, two-fluid or multifluid nozzles or with a rotating disk. The exit temperature is generally chosen in the range

from 45°C to 120°C, preferably from 60°C to 90°C, depending on the unit, on the Tg of the resin, and on the desired degree of drying.

- 5 In general, the spraying aid is used in a total amount of from 3 to 30% by weight, based on the polymeric constituents of the dispersion. In other words, the total amount of protective colloid prior to the drying operation should be from at least 3 to 30% by weight,  
10 based on the polymer fraction; it is preferred to use from 5 to 20% by weight based on the polymer fraction.

Suitable spraying aids are partially hydrolyzed polyvinyl alcohols; polyvinylpyrrolidones;  
15 polysaccharides in water-soluble form such as starches (amylose and amylopectin), celluloses and their carboxymethyl, methyl, hydroxyethyl, and hydroxypropyl derivatives; proteins such as casein or caseinate, soya protein, gelatin; ligninsulfonates, synthetic polymers  
20 such as poly(meth)acrylic acid, copolymers of (meth)acrylates with carboxyl-functional comonomer units, poly(meth)acrylamide, polyvinylsulfonic acids and their water-soluble copolymers; melamine-formaldehyde sulfonates, naphthalene-formaldehyde sul-  
25 fonates, and styrene-maleic acid and vinyl ether-maleic acid copolymers. Preferably, no protective colloids other than polyvinyl alcohols are used as spraying aids.

- 30 At the spraying stage it has in many cases been found advantageous to include up to 1.5% by weight of antifoam, based on the base polymer. In order to extend the storage life by improving the blocking stability, especially in the case of powders having a low glass  
35 transition temperature, the powder obtained can be provided with an antiblocking (anticaking) agent, preferably up to 30% by weight, based on the overall weight of polymeric constituents. Examples of

antiblocking agents are Ca or Mg carbonate, talc, gypsum, silica, kaolins, and silicates having particle sizes preferably in the range from 10 nm to 10  $\mu$ m.

- 5 The viscosity of the feed to be sprayed is adjusted by way of the solids content so as to give a value of < 500 mPas (Brookfield viscosity at 20 revolutions and 23°C), preferably < 250 mPas. The solids content of the dispersion to be sprayed is > 35%, preferably > 40%.

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In order to improve the performance properties, further additives can be added at the spraying stage. Examples of further constituents of dispersion powder compositions, present in preferred embodiments, are pigments, fillers, foam stabilizers, and hydrophobicizers.

15

- To produce the building adhesive, the polymer powder is mixed with the further formulation constituents such as cement, filler and other adjuvants in appropriate mixers, and homogenized. If desired, the dispersion powder composition may also be added in the form of an aqueous redispersion on the construction site (2-component adhesive). Preferably, a dry mix is prepared and the water required for processing is added immediately prior to processing. When preparing pastelike building adhesives, the water fraction is introduced first of all, the dispersion is added, and finally the solids are incorporated by stirring.

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- Typical cementitious building adhesive formulations contain from 5 to 80% by weight of cement, from 5 to 80% by weight of fillers such as quartz sand, calcium carbonate or talc, from 0.1 to 2% by weight of thickeners such as cellulose ethers, phyllosilicates, polyacrylates, from 0.5 to 60% by weight of the protective colloid stabilized polymer powders, and, if desired, further additives for improving stability,

35

processability, open time, and water resistance. The amounts in % by weight always refer to 100% by weight dry mass of the formulation. The cementitious building adhesive formulations mentioned are employed in particular for the laying of tiles of all kinds (earthenware, stoneware, including fine stoneware, ceramic, natural material tiles) both inside and outside, as tile adhesives, and before being used are prepared by stirring together with the appropriate amount of water.

The protective colloid stabilized polymer powders are also suitable for use in cement-free building adhesive formulations: for example, with the corresponding amount of gypsum instead of cement as inorganic binder in the abovementioned formulation. The cement-free building adhesive formulations are employed in particular for the laying of tiles of all kinds (earthenware, stoneware, including fine stoneware, ceramic, natural material tiles) in the interior sector as tile adhesives and as exterior insulation system adhesives for bonding polystyrene panels to facades.

The examples below serve to illustrate the invention:

#### Examples:

Emulsion polymerization was used to prepare polymer dispersions having a polymer composition of vinyl acetate:ethylene of 100:7 parts by weight. The dispersions were stabilized using 8% by weight, based on vinyl acetate, of a polyvinyl alcohol having a degree of hydrolysis of 88 mol% and a Höppler viscosity of 4 mPas. The amount and nature of the auxiliary monomers used (% by weight based on vinyl acetate) are reproduced in table 1.

Powder preparation:

5 The dispersions from the examples were admixed with 5%  
by weight (solids/solids) of polyvinyl alcohol having a  
degree of hydrolysis of 88 mol% and a Höppler viscosity  
of 4 mPas and were diluted with water to a spray  
viscosity of 250 mPas. The dispersion was then sprayed  
using a two-fluid nozzle. The spraying component used  
was air precompressed to 4 bar, and the droplets formed  
were dried cocurrently with air heated to 125°C. The  
dry powder obtained was admixed with 10% by weight,  
10 based on the copolymer, of commercial antiblocking  
agent (mixture of calcium magnesium carbonate and  
magnesium hydrosilicate).

15 Performance testing:

Redispersion behavior of the polymer films (R):

0.2 mm thick films of the dispersions of the above  
20 examples (before spray drying) were produced on glass  
plates and were dried at 105°C for 15 minutes. To  
examine the film redispersibility, one drop of water  
was applied to a homogeneous site of the test film  
using a pipette at room temperature, and after leaving  
25 it to act for 60 seconds the water drop was rubbed at  
the same site using the fingertip until the glass plate  
at this site was film-free, the film fragmented, or the  
film retained its integrity completely.

30 The redispersibility of the polymer films was assessed  
using the following evaluation scheme:

rating 1: film can be redispersed immediately by slight  
rubbing or redisperses automatically;

35 rating 2: film can be redispersed by rubbing, film  
fragments of low redispersibility possible;

rating 3: film can be redispersed only by vigorous  
rubbing, and film fragments are formed;

rating 4: film cannot be redispersed even by prolonged vigorous rubbing, but instead fragments.

Determination of the blocking resistance (B):

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To determine the blocking resistance, the dispersion powder was placed in an iron tube with a thread and then subjected to the load of a metal ram. Loading was followed by storage at 50°C for 16 hours in a drying cabinet. After cooling to room temperature, the powder was removed from the tube and the blocking stability was determined qualitatively by crushing the powder. The blocking stability was classified as follows:

- 1 = very good blocking stability  
15 2 = good blocking stability  
3 = satisfactory blocking stability  
4 = not stable to blocking, powder after crushing no longer free-flowing.

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Determination of the cement stability (CS):

A cement mixture was prepared by stirring to the following formulation:

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Portland cement	82.5 g
Calcite (CaCO <sub>3</sub> ) 10-40 μm	75 g
Quartz sand 200-500 μm	142 g
Dispersion powder	14.5 g
30 Water	85 g

The processability of the cement mixture was observed over a period of 2 hours and assessed qualitatively.

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Determination of the tensile bond strength:

The tensile bond strengths in the tile adhesive were examined in the following formulation (6% by weight polymer powder fraction):

	Quartz sand	586 parts
5	Portland cement	350 parts
	Cellulose	4 parts
	Dispersion powder	60 parts
	Water	240 parts

- 10 To test the tensile bond strength, the tile adhesives were applied to concrete slabs using a 5 mm toothed spatula. Subsequently, stoneware tiles measuring 5 x 5 cm<sup>2</sup> were placed on and weighted down for 30 seconds with a weight of 2 kg. Thereafter, the tiles
- 15 were subjected to the following conditions in accordance with DIN CEN 1897:

- 28T: 28 days of dry storage under standard conditions (DIN 50014, 23°C, 50% atmospheric humidity)
- 20 7T/21N: 7 days of dry storage under standard conditions, 21 days of wet storage in water at 20°C
- 14T/14T70°C/1T: 14 days of standard conditions, 14 days at 70°C in a drying oven, 1 day of standard conditions
- 25 Freeze/thaw: 7 days of dry storage under standard conditions, 21 days of wet storage in water at 20°C, 25 freeze/thaw cycles (frost storage at -15°C, water storage at 12°C)
- 30

- The tensile bond strength was determined in accordance with DIN 18156, following storage, using a peel instrument from the company Herion with a rate of load increase of 250 N/s. The measurements in N/mm<sup>2</sup>
- 35 represent averages of 5 measurements.

The results of testing are summarized in tables 1 and 2.



Auxiliary monomers:

5 Aa = acrylic acid,

VS = vinylsulfonic acid,

AAGa = acrylamidoglycolic acid

Amount = fraction of the auxiliary monomer in % by weight

pH = pH of the polymer dispersion

MFT = minimum film-formation temperature of the polymer dispersion in °C

R = redispersion behavior

CS = cement stability

(2) = tensile bond strength in N/mm<sup>2</sup> after 7T/21N storage

(3) = tensile bond strength in N/mm<sup>2</sup> after 14T/14T70°C/1T storage

30 (4) = tensile bond strength in N/mm<sup>2</sup> after freeze/thaw  
storage

Total (1-4) = total of the tensile bond strengths in  
N/mm<sup>2</sup>

35 The results in table 1 show that, even with  
modification of the vinyl ester polymers with auxiliary  
monomer units, powders having very good redispersion

behavior and cement stability are obtained which exhibit good blocking stability and storage stability.

Table 2 shows that, with the modification with auxiliary monomer units, a distinct improvement in the tensile bond strengths is obtained, and is maintained under all storage conditions. This improvement, however, occurs only within a narrow window, i.e., within a range from 0.5 to 1.0% by weight.

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Table 1:

Example	Auxiliary monomer	Amount % by weight	SC % by weight	pH	BF20 mPas	MFT °C	Dw	R	B	CS
C.Ex. A	none	0	55.0	4.1	400	5	950	1	1	yes
Ex. 1	AA	0.2	54.4	4.4	405	5	1097	1	1	yes
Ex. 2	AA	1.5	55.4	4.0	472	5	1134	1	1	yes
C.Ex. 3	AA	2.0	52.1	3.9	276	5	1180	1	1	yes
Ex. 4	Aa	0.2	55.0	4.2	450	6.5	1097	1	1	yes
Ex. 5	Aa	1.5	55.0	4.2	428	5	1097	1	1	yes
C.Ex. 6	Aa	2.0	52.7	4.2	371	6	1090	1	1	yes
C.Ex. 7	Aa	3.0	55.0	3.5	680	5	1160	1	1	yes
Ex. 8	AMPS	0.2	55.0	4.4	590	6	984	1	1	yes
Ex. 9	AMPS	1.5	55.1	4	560	5	1097	1	1	yes
C.Ex. 10	AMPS	2.0	54.6	4.2	815	6	1650	1	1	yes
C.Ex. 11	AMPS	3.0	55.2	4.1	630	6	1820	1	1	yes
Ex. 12	VS	0.2	54.8	4.4	428	6.5	1204	1	1	yes
Ex. 13	VS	1.5	55.4	4.4	500	5	1050	1	1	yes
C.Ex. 14	VS	2.0	52.6	4.3	395	8	1020	1	1	yes
Ex. 15	MAn	0.2	53.9	4.3	363	7	1322	1	1	yes
Ex. 16	MAn	1.5	54.8	3.7	457	6	1322	1	1	yes
Ex. 17	AAGa	1.5	55.0	3.8	750	5	1150	1	1	yes
C.Ex. 18	AAGa	2.0	52.8	4	310	6	1110	1	1	yes
Ex. 19	Ia	0.2	55.4	4.5	640	5	1120	1	1	yes
Ex. 20	Ia	1.5	52.4	4.5	346	3	1160	1	1	yes
C.Ex. 21	Ia	2.0	51.6	4.9	295	7	1120	1	1	yes

Table 2:

Example	Auxiliary monomer	Amount	(1)	(2)	(3)	(4)
C.Ex. A	none	0	1.67	0.72	1.64	0.62
Ex. 1	AA	0.2	2.06	0.9	1.91	0.88
Ex. 2	AA	1.5	1.95	1.11	2.31	0.95
C.Ex. 3	AA	2.0	1.67	0.6	1.21	0.59
Ex. 4	Aa	0.2	1.94	0.86	2.38	0.89
Ex. 5	Aa	1.5	1.74	0.85	1.94	0.92
C.Ex. 6	Aa	2.0	1.64	0.8	1.74	0.85
C.Ex. 7	Aa	3.0	1.61	0.55	2.04	0.44
Ex. 8	AMPS	0.2	2.06	0.9	1.94	0.63
Ex. 9	AMPS	1.5	1.76	1.12	1.62	1.03
C.Ex. 10	AMPS	2.0	1.65	0.95	1.55	0.8
C.Ex. 11	AMPS	3.0	1.47	0.67	1.53	0.7
Ex. 12	VS	0.2	2.12	1.1	2.11	0.95
Ex. 13	VS	1.5	2.28	1.05	2.26	1.05
C.Ex. 14	VS	2.0	1.69	0.57	1.81	0.58
Ex. 15	Man	0.2	2.13	0.86	2.28	0.87
Ex. 16	Man	1.5	2.11	0.9	2.11	0.83
Ex. 17	AAGa	1.5	1.53	0.58	2.17	0.61
C.Ex. 18	AAGa	2.0	1.46	0.64	1.6	0.57
Ex. 19	Ia	0.2	1.6	0.58	2.26	0.62
Ex. 20	Ia	1.5	1.38	0.55	1.77	0.71
C.Ex. 21	Ia	2.0	1.38	0.53	1.31	0.57